EINSTEIN'S PRESENCE*

J. Robert Oppenheimer † It is an honor to be in this company, the tenth year after Einstein's death, the fiftieth anniversary of his discovery of the general theory of relativity.

As the President has said, though I knew Einstein for two or three decades, it was only in the last decade of his life that we were close colleagues and something of friends. But I thought that it might be useful, because I am sure that it is not too soon — and for our generation perhaps almost too late — to start to dispel the clouds of myth and to see the great mountain peak that these clouds hide. As always, the myth has its charms; but the truth is far more beautiful.

Late in his life, in connection with his despair over weapons and wars, Einstein said that if he had to live it over again he would be a plumber. This was a balance of seriousness and jest that no one should now attempt to disturb. Believe me, he had no idea of what it was to be a plumber; least of all in the United States, where we have a joke that the typical behavior of this specialist is that he never brings his tools to the scence of the crisis. Einstein brought his tools to his crises; Einstein was a physicist, a natural philosopher, the greatest of our time.

What we have heard, what you all know, what is the true part of the myth, is his extraordinary originality. The discovery of quanta would surely have come one way or another, but he discovered them. Deep understanding of what it means that no signal could travel faster than light would surely have come; the formal equations were already known; but this simple, brilliant understanding of the physics could well have been slow in coming, and blurred, had he not done it for us. The general theory of relativity which, even today, is not well proved experimentally, no one but he would have done for a long, long time. It is in fact only in the last decade, the last years, that one has seen how a pedestrian and hard-working physicist, or many of them, might reach that theory and understand this singular union of geometry and gravitation, and we can do even that today only because some of the *a priori* open possibilities are limited by the confirmation of Einstein's discovery that light would be deflected by gravity.

Yet there is another side besides the originality. Einstein brought to the work of originality deep elements of tradition. It is only possible to discover in part how he came by it, by following his reading, his friendships, the meager record that we have. But of these deep-seated elements of tradition — I will not try to enumerate them all; I do not know them all — at least three were indispensable and stayed with him.

* Title added after the author's death.

The first is from the rather beautiful but recondite part of physics that is the explanation of the laws of thermodynamics in terms of the mechanics of large numbers of particles, statistical mechanics. This was with Einstein all the time. It was what enabled him from Planck's discovery of the law of black body radiation to conclude that light was not only waves but particles; particles with an energy proportional to their frequency and momentum determined by their wave-number, the famous relations that de Broglie was to extend to all matter, to electrons first and then clearly to all matter.

It was this statistical tradition that led Einstein to the laws governing the emission and absorption of light by atomic systems. It was this that enabled him to see the connection between de Broglie's waves and the statistics of light-quanta proposed by Bose. It was this that kept him an active proponent and discoverer of the new phenomena of quantum physics up to 1925.

The second and equally deep strand — and here I think we do know where it came from — was his total love of the idea of a field: the following of physical phenomena in minute and infinitely subdividable detail in space and in time. This gave him his first great drama of trying to see how Maxwell's equations could be true. They were the first field equations of physics; they are still true today with only very minor and well-understood modifications. It is this tradition which made him know that there had to be a field theory of gravitation, long before the clues to that theory were securely in his hand.

The third tradition was less one of physics than of philosophy. It is a form of the principle of sufficient reason. It was Einstein who asked what do we mean, what can we measure, what elements in physics are conventional? He insisted that those elements that were conventional could have no part in the real predictions of physics. This also had roots: for one the mathematical invention of Riemann, who saw how very limited the geometry of the Greeks had been, how unreasonably limited. But in a more important sense, it followed from the long tradition of European philosophy, you may say, starting with Descartes — if you wish, you can start it in the thirteenth century, because in fact it did start then — and leading through the British empiricists, and very clearly formulated, though probably without influence in Europe, by Charles Peirce: one had to ask how do we do it, what do we mean, is this just something that we use to help ourselves in calculating, or is it something that we can actually study in nature by physical means. For the point here is that the laws of nature not only describe the results of observations, but the laws of nature delimit the scope of observations. That was the point of Einstein's understanding of the limiting character of the velocity of light; it also was the nature of the resolution in quantum theory, where the quantum of action, Planck's constant, was recognized as limiting the fineness of the transaction between the system studied and the machinery used to study it, limiting this fineness in a form of atomicity quite different from and much more radical

than any that the Greeks had imagined or that was familiar from the atomic theory of chemistry.

In the last years of Einstein's life, the last twenty-five years, his tradition in a certain sense failed him. They were the years he spent at Princeton and this, though a source of sorrow, should not be concealed. He had a right to that failure. He spent those years, first, in trying to prove that the quantum theory had inconsistencies in it. No one could have been more ingenious in thinking up unexpected and clever examples, but it turned out that the inconsistencies were not there; and often their resolution could be found in earlier work of Einstein himself. When that did not work, after repeated efforts, Einstein had simply to say that he did not like the theory. He did not like the elements of indeterminacy. He did not like abandonment of continuity or of causality. These were things that he had grown up with, saved by him, and enormously enlarged; and to see them lost, even though he had put the dagger in the hand of their assassin by his own work, was very hard on him. He fought with Bohr in a noble and furious way, and he fought with the theory which he had fathered but which he hated. That is not the first time it has happened in science.

He also worked with a very ambitious program, to combine the understanding of electricity and gravitation in such a way as to explain what he regarded as the semblance — the illusion — of discreteness, of particles in nature. I think that it was clear then, and I believe it to be obviously clear today, that the things that this theory worked with were too meager, left out too much that was known to physicists but had not been known much in Einstein's student days. Thus it looked like a hopelessly limited and historically rather accidentally conditioned approach. Although Einstein commanded the affection, or, more rightly, the love of everyone for his determination to see through his program, he lost most contact with the profession of physics, because there were things that had been learned which came too late in life for him to concern himself with them.

Einstein was indeed one of the friendliest of men. I had the impression that he was also, in an important sense, alone. Many very great men are lonely; yet I had the impression that although he was a deep and loyal friend, the stronger human affections played a not very deep or very central part in his life taken as a whole. He had of course incredibly many disciples, in the sense of people who, reading his work or hearing it taught by him, learned from him and had a new view of physics, of the philosophy of physics, of the nature of the world that we live in. But he did not have, in the technical jargon, a school. He did not have very many students who were his concern as apprentices and disciples. And there was an element of the lone worker in him, in sharp contrast to the teams we see today, and in sharp contrast to the highly co-operative way in which some other parts of science have developed. In later years, he had people working with him. They were typically called assistants and they

had a wonderful life. Just being with him was wonderful. His secretary had a wonderful life. The sense of grandeur never left him for a minute, nor his sense of humor. The assistants did one thing which he lacked in his young days. His early papers are paralyzingly beautiful, but there are many errata. Later there were none. I had the impression that, along with its miseries, his fame gave him some pleasures, not only the human pleasure of meeting people but the extreme pleasure of music played not only with Elizabeth of Belgium but more with Adolphe Busch, for he was not that good a violinist. He loved the sea and he loved sailing and was always grateful for a ship. I remember walking home with him on his seventy-first birthday. He said, "You know, when it's once been given to a man to do something sensible, afterward life is a little strange."

Einstein is also, and I think rightly, known as a man of very great goodwill and humanity. Indeed, if I had to think of a single word for his attitude towards human problems, I would pick the Sanscrit word "Ahinsa", not to hurt, harmlessness. He had a deep distrust of power; he did not have that convenient and natural converse with statesmen and men of power that was quite appropriate to Rutherford and to Bohr, perhaps the two physicists of this century who most nearly rivalled him in eminence. In 1915, as he made the general theory of relativity, Europe was tearing itself to pieces and half losing its past. He was always a pacifist. Only as the Nazis came into power in Germany did he have some doubts, as his famous and rather deep exchange of letters with Freud showed, and began to understand with melancholy and without true acceptance that, in addition to understanding, man sometimes has a duty to act.

After what you have heard, I need not say how luminous was his intelligence. He was almost wholly without sophistication and wholly without worldliness. I think that in England people would have said that he did not have much "background," and in America that he lacked "education." This may throw some light on how these words are used. I think that this simplicity, this lack of clutter and this lack of cant, had a lot to do with his preservation throughout of a certain pure, rather Spinoza-like, philosophical monism, which of course is hard to maintain if you have been "educated" and have a "background." There was always with him a wonderful purity at once childlike and profoundly stubborn.

Einstein is often blamed or praised or credited with those miserable bombs. This is not in my opinion true. The special theory of relativity might not have been beautiful without Einstein; but it would have been a tool for physicists, and by 1932 the experimental evidence for the inter-convertibility of matter and energy, which he had predicted, was overwhelming. The feasibility of doing anything with this in such a massive way was not clear until seven years later, and then almost by accident. This was not what Einstein really was after. His part was that of creating an intellectual revolution, and discovering more than any scientist of our time how profound were the errors made by

men before then. He did write a letter to Roosevelt about atomic energy. I think this was in part his agony at the evil of the Nazis, in part not wanting to harm any one in any way; but I ought to report that that letter had very little effect, and that Einstein himself is really not answerable for all that came later. I believe he so understood it himself.

His was a voice raised with very great weight against violence and cruelty wherever he saw them and, after the war, he spoke with deep emotion and I believe with great weight about the supreme violence of these atomic weapons. He said at once with great simplicity: now we must make a world government. It was very forthright, it was very abrupt, it was no doubt "uneducated," no doubt without "background;" still all of us in some thoughtful measure must recognize that he was right.

Without power, without calculation, with none of the profoundly political humor that characterized Gandhi, he nevertheless did move the political world. In almost the last act of his life, he joined with Lord Russell in suggesting that men of science get together and see if they could not understand one another and avert the disaster which he foresaw from the arms race. The so-called Pugwash movement which has a longer name now, was the direct result of this appeal. I know it to be true that it had an essential part to play in the Treaty of Moscow, the limited test-ban treaty, which is a tentative, but to me very precious, declaration that reason might still prevail.

In his last years, as I knew him, Einstein was a twentieth century Ecclesiastes, saying with unrelenting and indomitable cheerfulness, "Vanity of vanities, all is vanity."

THE UNIFIED FIELD THEORY

Werner Heisenberg Among the many ideas which Einstein has pursued in connection with his theory of general relativity, his proposal of a unified theory has aroused the widest interest on account of its philosophical implication. Einstein has suggested that such different phenomena as gravitation, electromagnetism and material bodies could ultimately be described by one fundamental field or system of fields; that all the different empirical laws of nature could be expressed by one universal system of non-linear equations for the components of this field. From a philosophical point of view this possibility looks very attractive. Different groups of phenomena, like gravitation and electricity, can scarcely be separated completely. They may influence each other, and therefore the laws of nature responsible for them cannot be completely independent. The unified field theory would contain the different laws as special cases and would at the same time establish the connection and thereby state the structure of nature.

SCIENCE AND SYNTHESIS

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